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Transmission electron microscopy of magnetite plaquettes in Orgueil

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Magnetite sometimes takes the form of a plaquette – barrel-shaped stack of magnetite disks – in carbonaceous chondrites (CC) that show evidence of aqueous alteration [1-3]. The asymmetric nature of the plaquettes caused Pizzarello and Groy [4] to propose magnetite plaquettes as a naturally asymmetric mineral that can introduce symmetry-breaking in organic molecules. Our previous synchrotron X-ray computed microtomography (SXRCT) and electron backscatter diffraction (EBSD) analyses of the magnetite plaquettes in fifteen CCs indicate that magnetite plaquettes are composed of nearly parallel discs, and the crystallographic orientations of the discs change around a rotational axis normal to the discs surfaces [1].

In order to further investigate the nanostructures of magnetite plaquettes, we made two focused ion beam (FIB) sections of nine magnetite plaquettes from a thin section of CI Orgueil for transmission electron microscope (TEM) analysis. The X-ray spectrum imaging shows that the magnetite discs are purely iron oxide Fe_3O_4 (42.9 at% Fe and 57.1 at% O), which suggest that the plaquettes are of aqueous origin as it is difficult to form pure magnetite as a nebular condensate [5]. The selected area electron diffraction (SAED) patterns acquired across the plaquettes show that the magnetite discs are single crystals. SEM and EBSD analyses suggest that the planar surfaces of the magnetite discs belong to the {100} planes of the cubic inverse spinel structure [1], which are supported by our TEM observations. Kerridge et al. [5] suggested that the epitaxial relationship between magnetite plaquette and carbonate determines the magnetite face. However, according to our TEM observation, the association of magnetite with porous networks of phyllosilicate indicates that the epitaxial relationship with carbonate is not essential to the formation of magnetite plaquettes. It was difficult to determine the preferred rotational orientation of the plaquettes due to the symmetry of the cubic structure, however, we are able to observe small but consistent rotational orientation across several discs within a plaquette.

[1] Chan et al. (2016) Am. Mineral. [2] Jedwab J. (1971) Icarus, 15, 319-340. [3] Hua X. and Buseck P.R. (1998) MAPS, 33, A215-A220. [4] Pizzarello S. and Groy T.L. (2011) GCA, 75, 645-656. [5] Kerridge J.F. et al. (1979) Science, 205, 395-397.